APPLIED THEORY

SUMMARY
- Finds that the common practice of PowerPoint is heavily influenced by PowerPoint's defaults
- Finds that the common practice of PowerPoint does not follow cognitive principles of multimedia learning
- Shows that the assertion–evidence slide structure is much more in line with multimedia learning principles

Common Use of PowerPoint versus the Assertion–Evidence Structure: A Cognitive Psychology Perspective

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INTRODUCTION

Since 2001, harsh criticism of PowerPoint's presentation slide structure has surfaced in several popular publications: "Absolute PowerPoint," *The New Yorker* (Parker 2001); "PowerPoint Is Evil," *Wired* (Tufte 2003b); "Is PowerPoint the Devil," *The Chicago Tribune* (Keller 2003); and "Research Points the Finger at PowerPoint," *The Sydney Morning Herald* (Patty 2007). Because Microsoft PowerPoint controls 95% of the market for presentation slideware (Parker 2001), its default structure certainly deserves scrutiny. However, what is more important than analyzing the default structure of PowerPoint is to analyze the slide structures that people actually use. For that reason, in technical communication, the key question is the following: what slide structures are commonly used for presenting science and technology?

To answer this question fully, one would have to examine representative samples of slides from the different types of technical presentations: project, research, design, marketing, and so forth. One would also have to consider presentation slides created in the major languages: Mandarin Chinese, English, Spanish, and Arabic. Moreover, one would to have to consider slides in each of these different languages created by native speakers versus nonnative speakers. In short, the challenge of determining the common practice of slide design in technical communication is daunting.

Nonetheless, in this paper, we attempt a "first-cut" estimate of what the common practice is for slides in technical presentations. Having such an estimate, even if rough, would be valuable because it would put into perspective the criticism of PowerPoint published thus far. For example, if only a relatively small percentage of slides follow PowerPoint's defaults, questions about the efficacy of those defaults are moot.

In our first-cut estimation, we analyzed >2,000 slides from project and research presentations given in English by three different groups: professionals at North American laboratories and companies; scholars at a North American engineering conference; and nonnative speakers of English attending graduate schools in Northern Europe. Why focus on project and research presentations? From a perspective of science and technology, these types of presentations are important, often occurring before large audiences. From the perspective of data analysis, these types of presentations include slides with a wide range of purposes—from primarily informative to primarily persuasive. From a logistical perspective, representative sets of these types of presentations are accessible within the public domain and are not as limited by proprietary restrictions as other presentation types are.

In our analysis, we looked for the frequency of specific slide features and the degree to which those features adhered to or broke away from PowerPoint's default settings for placement and form of both the headline and the body. In our analysis, we did not specifically target slides created by the readers of this journal: technical managers, technical editors, technical artists, technical writers, and technical communication instructors. The reason is that *Technical communication* has published several recent articles that critically analyze the default slide structure of PowerPoint (Doumont 2005; Farkas 2009; Manning and Amare 2006)

Manuscript received 9 January 2009; revised 3 July 2009; accepted 31 July 2009.

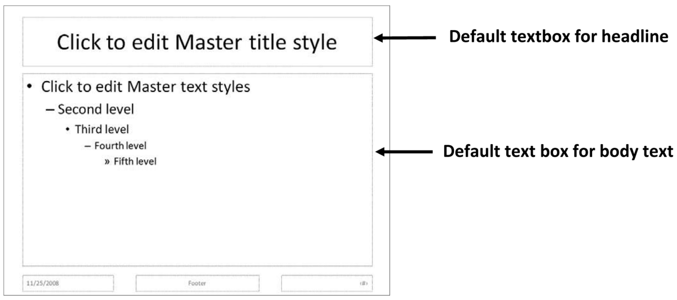

Figure 1. Default settings of PowerPoint's slide master.

and support alternative structures (Alley and Neeley 2005; Jennings 2009; Markel 2009). For that reason, targeting this journal's audience would likely not represent practices by the average user in science and technology. Although some slides in our sample were possibly created or influenced by readers of this journal, many more were not.

Once we have answered the question of what is the common practice of slides in technical communication, the next logical question is whether that common practice meets the established cognitive psychology principles for how people learn. In other words, is the common practice of slides in technical communication effective at helping people understand and remember the information? To address this question, we use principles of multimedia learning to interpret our analysis findings. These learning principles are from experimental research in cognitive psychology.

After defining and assessing the common practice of slides in technical communication, we consider an alternative slide structure called the assertion–evidence (A–E) slide structure, which several technical communicators tout as being more effective for technical presentations (Alley and Neeley 2005; Atkinson 2005; Doumont 2007; Jennings 2009; Markel 2009). Granted, other interesting alternatives to PowerPoint's structure exist that make the same claim—for example, the *Presentation Zen* approach of Reynolds (2008) and the *slide:ology* approach of Duarte (2008). However, here we consider the A–E structure because the specificity of its guidelines (Alley and Neeley 2005) are well suited for analysis. As with the common practice structure, we analyze this A–E structure in light of multimedia learning principles and present recommendations for those who use slides in technical presentations.

DEFAULT SETTINGS OF POWERPOINT

Figure 1 shows PowerPoint's default master slide, which contains the program's key default settings. Except for changes in the choice of typeface and the number of slide masters, these settings have essentially remained the same since the program's creation in the mid-1980s by an entrepreneur, Robert Gaskins, and a computer scientist, Dennis Austin (Gomes 2007). The original typeface for PowerPoint was a version of Times New Roman. This default typeface changed to Arial in the 1990s. In PowerPoint 2007, the typeface changed again, this time to Calibri. For more discussion about audience perceptions of typefaces in PowerPoint slides, see Mackiewicz (2007). In addition to changes in typeface, later versions of PowerPoint included additional slide masters that the user can choose. However, because the user has to maneuver two levels into the program's hierarchy to select these alternative slide masters, we have focused on the default settings.

One of PowerPoint's defaults calls for a centered headline in a large typeface: 44 points. Because of the size and position of the text block, our expectation is that this default leads presenters to create short headlines—no more than six words as in the instructional wording of this default. Because the headline is so short, the headline would most likely be a phrase, such as "Computational Results," rather than a sentence: "Computational results show that the fillet eliminates the leading edge vortex" (Alley and Neeley 2005).

A second default concerns the way text is incorporated into the slide's body. This default, which originated during a time when images were difficult to incorporate into computer programs, calls for text to come in as a bulleted list that automatically fills a large text box. Because of this default, our expectation is that most slides contain such lists, that the number of words in these lists is significant, and that such lists reduce the space available for graphics.

In essence, these default settings encourage presenters to create slides that have a topic–subtopic structure. That is, the phrase headline identifies the main topic or idea of the slide, and the bulleted list beneath the headline serves to identify multiple subordinate ideas related to the overall headline phrase. In the literature, this assumed structure has received strong criticism. For an example of this criticism, see *The Cognitive Style of PowerPoint* by Tufte (2003a).

COMMON PRACTICE IN POWERPOINT SLIDE DESIGN

As mentioned, the defaults on the master slide might not necessarily correlate with what occurs in common practice. Although these defaults would seem to lead presenters to create a topic–subtopic structure for slides, a more important question is as follows: what are the slide structures that are used in common practice of technical presentations? In other words, how much do the default features of PowerPoint influence common practice in technical communication?

To address this question, we examined slides from three distinctly different technical communication situations to determine the influence of PowerPoint's defaults.

TABLE 1. COMMON PRACTICE STATISTICS ON SLIDE STRUCTURE

	Professionals: industry, laboratories		U.S. conference attendees		International PhD students	
Slide feature	Mean	SD	Mean	SD	Mean	SD
Percent of slides per set with phrase headline	92	9	84	19	94	9
Percent of slides per set with bullet list	63	27	69	21	75	22
Percent of slides per set with phrase headline and bullet list	59	27	63	24	71	24
Number of slide sets	36		48		33	
Total number of slides	501		1,009		515	

The following situations were examined: (a) research and project presentations created by professionals from government, industry, and laboratories; (b) research presentations created by scholars at a North American engineering conference; and (c) research presentations created by engineering and science PhD students representing 16 different countries in which English is not the native language. In each case, we aimed for a quality of slides that would be above average. The rationale here is that, if these above-average slides do not follow cognitive psychology principles for communication, the typical slides in those situations would not either.

For the first situation, we examined 501 slides from 36 presentations given by technical professionals at six corporations, laboratories, and agencies: the Army Research Laboratory, Brookhaven National Laboratory, the Environmental Protection Agency, the National Institute of Occupational Safety and Health, Sandia National Laboratories, and United Technologies. The sampling consisted of 36 sets of slides submitted to a presentations course by participating professionals. The submission assignment called for a strong set of slides that the participant had recently created.

The second situation consisted of slides delivered at an engineering conference in North America. For this situation, we considered 48 sets of PowerPoint slides that arose from presentations given at the 2008 American Society of Engineering Education Conference. Of these presentations, 3 were from plenary sessions, 31 received best paper nominations, and 14 came from the Educational Research Methods Division, which is widely considered to be the most selective division in the conference. Again, an implicit assumption is that significant effort went into these slides, making them appropriate representatives of this category. Moreover, because of their interest in education, we assumed that the engineers at this conference were more likely than engineers at typical technical conferences to be sensitive to methods that promote audience comprehension.

The final situation consisted of 33 presentations (for a total of 515 slides) created by international PhD students in science and engineering. These 33 students came from 16 different countries in Europe, Asia, Africa, and South America. None of these countries have English as their native language. Before a technical communication workshop (which was held in Northern Europe), each student was asked to submit the slides from the best presentation that he or she had given in the past year. Most slides came from research seminars and thesis defenses.

Within each set of slides, we limited our analysis to presentation slides in which the purpose was to communicate technical information for understanding and retention. Not considered were title slides (which often included much text to identify speakers and their institutions), slides to give acknowledgments or disclaimers, or slides to serve as placeholders in a presentation (such as a *Questions* slide at the end).

Table 1 shows the results of the analysis for the first major classification of our sample—the structure of the slides. As hypothesized, the headline default of PowerPoint strongly influences the structure of the headline. For each situation, >80% of slides per set have a phrase headline. This statistic has important implications because the headline frames the visual aid for both the presenter and the audience. A phrase headline serves to identify the topic of the slide—in general, the shorter the phrase, the less well defined the topic.

Second, as hypothesized, the body text default of PowerPoint strongly influences the structure of the slide's body, with >60% of slides per set in each situation having a bullet list. This statistic is an important finding. Although Manning and Amare (2006) point out that a bullet list of two to four items can be an effective strategy to provide emphasis, they also point out that using bullet lists too often dilutes that effect of emphasis. Having bullet lists on >60% of the slides is much too often.

Another problem with having bullet lists so often on presentation slides is that the practice increases the risk of having too much text, thus reducing audience comprehension (Tufte 2003a). When a presenter is talking, the projection of a large amount of written text can overwhelm the limited capacity attention and language-based resources within working memory of the audience. Put another way, comprehension suffers when competing language-based information is presented through visual and auditory means (Baddeley 2003).

A third problem with having bullet lists so often on presentation slides is that the practice increases the risk of the presenter not communicating the connections between the listed details. Using a bulleted list makes it more difficult for the presenter to succinctly differentiate for the audience the cyclical, sequential, causal, or other more complex relationship between details (Shaw and colleagues 1998; Tufte 2003a). These connections are important, however, if audiences are to understand complex topics. Although the latest versions of PowerPoint offer "SmartArt Graphic" templates for flow charts, sequential lists, and hierarchical arrangements, some of these provide automated bullet lists inside them. As a result, audiences may still struggle to figure out the relationships between ideas written on the slide while listening to the presenter at the same time.

In our analysis, the combination of these two defaults led to 59% or more of the slides per set in each situation having a topic–subtopic structure, which correlates to a phrase headline being supported by a bullet list. Moreover, most of the slides with this topic–subtopic structure did not have any graphics. A prototypical slide of this case in which no graphics exist is shown in Figure 2. For this category of slides, this particular slide is representative of the typical number of lines and words. Not reflected here is any decoration in the background, which was the case for almost one half of the slide sets that we examined.

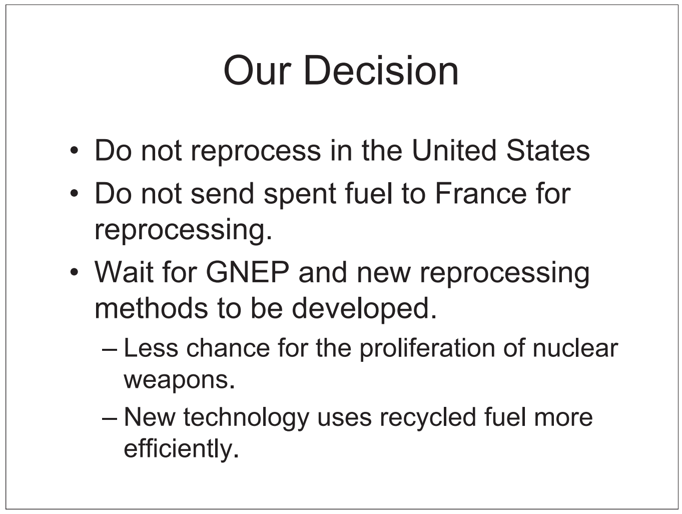

Figure 2. Prototypical slide for topic–subtopic structure with no graphic.

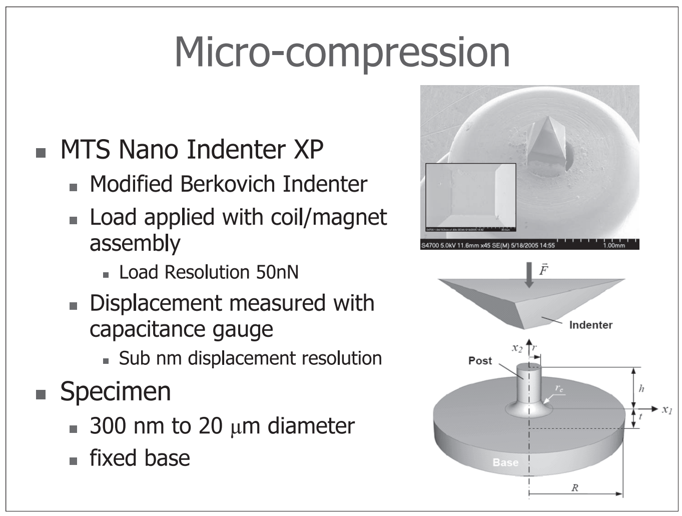

Figure 3. Prototypical slide for topic–subtopic structure with a graphic.

Figure 3 shows a prototypical slide for the topic–subtopic structure that includes a graphic (photograph, drawing, diagram, graph, or table). For this category of slides, the prototypical slide is representative not only in structure, but also in the number of lines and words. Again, not reflected here is any decoration in the background.

Whereas Table 1 showed the percentages of the different slide structures that one would expect in a typical technical presentation, Figure 4 shows a visual composite of those structures. For this composite, the three situations that we analyzed (professionals, scholars, and international PhD students) had equal weighting. The top two rows of Figure 4 represent the 65% of slides per set that one would expect to have a topic–subtopic structure. The top row depicts the portion of topic–subtopic slides with text only, and the second row presents the portion of topic–subtopic slides that also included graphics (photographs, drawings,

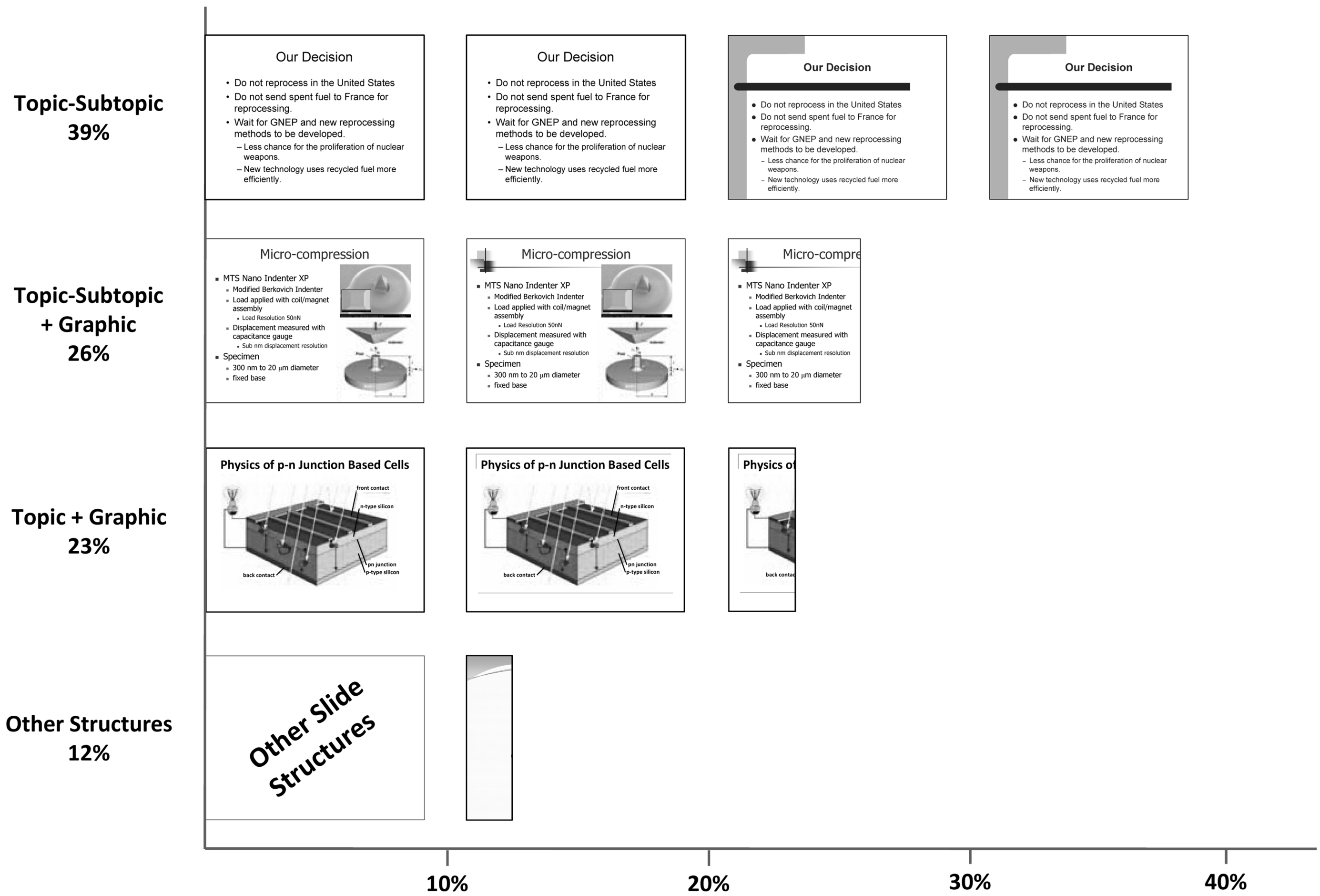

Figure 4. Composite of slides representing the common practice in technical communication.

diagrams, films, graphs, or tables). As found in our sampling of slides, about one half of the slide sets had a decorative background. In each row of Figure 4, that percentage of decorative backgrounds is reflected in the slide(s) on the right. Note that, in our analysis, no decoration included both dark type on light background and light type against a dark background. Also, in our analysis, institutional logos were not considered decoration. The third row of slides in Figure 4 represents the 23% of slides that have a topic phrase supported by a graphic. Finally, the bottom row represents the remaining 12% of slides that have a variety of headlines (sentence, question, or no headline) supported in different ways (graphic, single text block, or listing of subtopics).

Overall, our results show the strong influence that PowerPoint's default settings have on the slides that technical communicators in professional and academic settings create. Approximately 65% of slides per set conformed to the topic–subtopic structure of PowerPoint's default master slide. Moreover, most of these topic–subtopic slides did not have a graphic. In the next section, as we turn to the question of the effect of this influence of PowerPoint on the comprehension and retention of information by audiences, we evoke principles of multimedia learning. In this next section, we also continue to present the results of our common-practice analysis from the perspective of the amount of text on the slides, and, where relevant, the type of images that were typically included.

APPLICABLE PRINCIPLES FROM COGNITIVE PSYCHOLOGY

High-quality technical presentations call for visual aids that support the audience's comprehension of the presenter's intended message. In designing these visual aids, care must be taken that the presenter avoids imposing too much cognitive load on audience members. Cognitive load refers to the degree of effort, strategy, and processing capacity that an individual must exert to understand information. Two theories within cognitive psychology are important in assessing the cognitive load of a presentation slide: the theory of cognitive load and dual code theory.

According to the theory of cognitive load (Paas and colleagues 2003), information can be characterized on a continuum from low to high element interactivity. Low interactivity implies that individual concepts can be understood without the need to reference other information; high interactivity implies the opposite. In fact, highly interactive informational elements can only be partially understood if elements are not considered in relation to one another (Chandler and Sweller 1991). Understanding highly interactive information, however, places a high cognitive load or demand on the audience member's short term working memory system—the limited capacity memory system that acts as a gateway to long-term memory formation. For that reason, particular attention must be paid to the way in which information is presented to avoid increasing the difficulty level to the point where comprehension breaks down.

Sweller (2005) differentiated between two types of cognitive load: intrinsic and extraneous. Each has separate causes, but each can tax our attentional and memory systems to the point where learning breaks down. Intrinsic cognitive load is load that is inherent within the information being presented. Understanding highly interactive information, such as the how the parts of a complex system affect one another, places a high intrinsic cognitive load on the learner—particularly the novice learner. Keeping up with a presentation of complex information requires a great deal of working memory capacity to process the information and manipulate it to understand the relationships among its elements. To help make it easier for the audience, a presenter can try to control intrinsic load by making decisions about the complexity of the content that he or she will present and by reducing the number of elements that must be held in memory at the same time (Ayres and van Gog 2008). Depending on the purpose of the presentation, however, simplification may not always be possible or desirable. At times, a presenter simply must take on the challenge of talking about complex and difficult content.

As a professional who plans to convey technical information, it can be helpful to consider the idea of intrinsic cognitive load. For example, it is often easier to simply list the key concepts that a talk must cover than it is to explicitly show the spatial, temporal, or causal relationships between those concepts. However, pictorially showing relationships will help the audience understand the connections between those concepts. Using visual explanations also helps the presenter to convey the interactivity of the information, thereby reducing intrinsic cognitive load for the audience.

Second, it is often helpful to make explicit for the audience the assumptions or concepts that a presenter, who is often a content area expert, may take for granted. In other words, the presenter may need to explain additional concepts to be fully understood. How does the need for an explanation of additional concepts relate to the default structure of PowerPoint slides? The need arises in part because the topic–subtopic structure does not easily accommodate the depiction of explicit connections between concepts. In fact, we contend that honing the central message of each part of the presentation is easier if it is not done in accordance with the default slide structure that PowerPoint offers. Instead, by carefully anchoring each slide with an assertion that is articulated with a sentence headline, the presenter becomes aware of both the relationships between informational elements and whether additional supportive information is needed to lay the ground work for the main concept.

Although intrinsic load can arise from the inherent complexity of the content, extraneous cognitive load can arise from the method by which information is presented (Sweller 2005). When translated into the realm of a PowerPoint presentation, extraneous load can be influenced by how information is presented on a slide, including the amount and format of the information. Depending on the way that a presenter's visual aids are structured, extraneous load may be increased or decreased and may therefore impact audience members' comprehension in a negative or positive way. In technical presentations, where the nature of the information may be complex, sensitive, or high stakes, it is important to think about the structure and content of slides to reduce any extraneous processing that audience members have to do to grasp the key ideas at that moment in time. In summary, presentation slides need to be sensitive both to the intrinsic load created by the presentation of complex information to an audience who may be unfamiliar with that information and to the extraneous load that can occur when the delivery format fails to support the integration of concepts into a cohesive mental model. The default settings of PowerPoint are unsympathetic to both of these needs.

Dual code theory (Paivio 1986) and principles of multimedia learning (Mayer 2005a, 2005b) offer some insight into how text and images can be used to counter extrinsic cognitive load. Dual code theory states that information is more easily learned when verbal and image-based formats are meaningfully integrated together rather than when one or the other format is used exclusively (Clark and Paivio 1991; Paivio 1986). Put another way, every audience member has two cognitive pathways for understanding information: a verbal pathway, which processes words that are heard or read, and a pathway for images (Baddeley 2003). In a presentation, if the audience has to simultaneously listen to words spoken by the presenter and read many words on a projected slide, the verbal track can easily become overloaded. However, overload is less likely when those written words are replaced by images, which the audience processes through the nonverbal track (Paivio 1986). In fact, the integration of verbal and visual information can be beneficial for learning.

For that reason, helping individuals comprehend information that invokes high intrinsic load, while taking efforts to eliminate extraneous cognitive load results in superior-quality comprehension, retention, and transfer of information after learning has taken place (Sweller 2005). Therefore, logical questions for those interested in the effectiveness of presentation slides are how do common practice slides increase or decrease audience comprehension and how can presentation slides optimize intrinsic load while minimizing extrinsic load? Answers and solutions could more effectively allow presenters to reach their communication goals.

MULTIMEDIA PRINCIPLES APPLIED TO COMMON PRACTICE SLIDES

Research in multimedia learning has generated a number of principles of instructional design that are congruent with the dual code and cognitive load perspectives. According to Mayer (2005a, 2005b), learning from multimedia presentations—including PowerPoint presentations—is most successful when certain principles are followed. In effect, these principles reduce extraneous processing of information by the audience. One principle is that individuals learn better when words and pictures are presented, rather than when words alone are presented. This principle is termed the multimedia principle (Mayer 2001) and is in line with the dual code theory.

A second principle is that audiences show superior comprehension and retention when extraneous information is removed from the presentation (Mayer 2005b; Sweller 2005). This principle is referred to as the principle of coherence in multimedia learning. For PowerPoint in particular, this situation pertains to the amount and type of the information contained on the slide.

A third and critical principle is that of signaling (Mayer 2005b). Learners benefit from presentations that highlight the organization of essential material. This principle mirrors cognitive load theory in its emphasis on the need to clarify relationships that allow understanding of highly interactive information.

A final principle to note relates to the manner in which the slides are presented. The principle of redundancy states that "people learn more deeply from graphics and narration than from graphics, narration, and online text" (Mayer 2005b, 183). Simply stated, reading and hearing identical verbal information simultaneously can significantly reduce the comprehension by audience members, particularly when individuals have to split their visual attention between text and other elements presented on the screen (Mayer and colleagues 2001). Also, the more text that is placed on the slide, the more tempting it is for the speaker to simply read from that slide. For these reasons, audiences can learn more deeply when the speaker orally explains a graphical depiction.

In this section, we assert that the common practice of the PowerPoint slide—defined here as the pervasive topic–subtopic structure of the slides in our sample—is in conflict with the above principles. This conflict leads to two primary outcomes. First, the topic–subtopic structure, which presenters in our sample used for roughly two thirds of the PowerPoint slides they created, does not convey the interactivity among informational elements. Put another way, the topic–subtopic structure of PowerPoint violates the multimedia principles of coherence and signaling and increases extraneous cognitive load by requiring audience members to expend valuable working memory resources to comprehend relationships among concepts. Audience members need to hold concepts in memory while considering the relationship between them. The more elements that need to be held, the higher the level of cognitive load (Ayres and van Gog 2008). Second, the topic–subtopic structure often leads the presenter to increase extraneous load by adding a great deal of nonvital information to the slide. Introducing nonessential information has been shown to reduce learning from multimedia presentations (Mayer and colleagues 2001).

Common practice PowerPoint slides hide the connections between informational elements

In two thirds of the slides that we analyzed, the phrase headline specifies a general topic, and each bulleted or sub-bulleted item seems as equally important and subordinate to that overall topic. At first glance, one would think that such a short headline would benefit the learner. However, a short headline instead leads authors to begin the creation of the slide with a topic such as "U.S. Energy Use." Such a headline neither signals the audience to the perspective taken by the presenter on the topic nor highlights the organization of information. A phrase headline does not help the presenter to consider the appropriate concepts the audience will need to understand his or her perspective on the topic. A phrase headline also does not help the presenter to minimize the number of informational elements on the slide to manage the risk of high intrinsic cognitive load. In contrast, both signaling and highlighting would occur with a headline such as "The U.S. has only 5% of the world's population, but consumes 25% of the world's energy." This headline introduces U.S. energy use from the perspective of the proportion of the world's total popula-

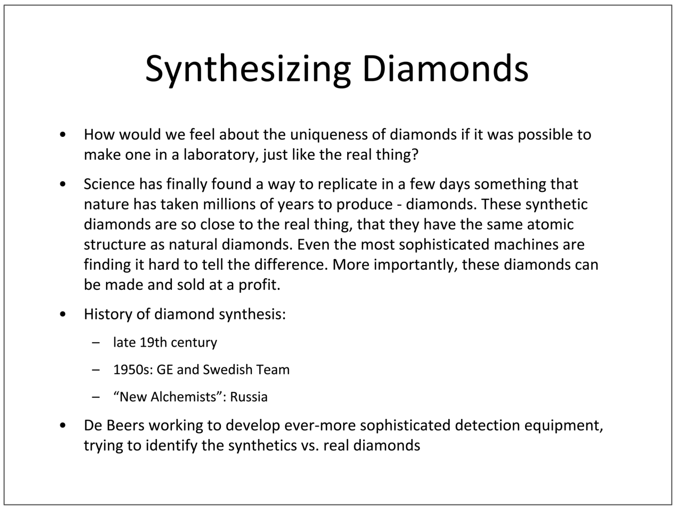

Figure 5. An example of a topic–subtopic slide that violates multimedia principles of learning.

tion that resides there and immediately alerts the audience to the presenter's assertion that there is a discrepancy.

The topic–subtopic structure also leaves out the specific connections between the headline and each of the bulleted items. Therefore, the relationships between the bulleted items themselves are not immediately apparent. This lack of connection violates the signaling principle as described above. The structure may inadvertently promote irrelevant processing of information by audience members, and therefore extraneous cognitive load, as they struggle to connect the meaning of the phrase headline and the body text. This effect would be exacerbated if the information is complex or unfamiliar to the audience.

As an example of how the common practice of PowerPoint slides reduces the ability of audience members to detect informational interactivity, consider the slide in Figure 5. Without having a defined perspective on the topic of "synthesizing diamonds," the slide wanders from the opinion of people on synthetic diamonds, to the closeness of synthetic diamonds to real diamonds, to the history of synthetic diamonds, and then to the detection of synthetic diamonds by those who mine diamonds. In addition, the presenter's decision to fill the bulleted textbox with text has led to the addition of redundant information. The slide violates the multimedia principle, the principle of coherence, and the principle of signaling. Moreover, because the slide contains so much text, the presenter is likely to read aloud the text on this slide, especially if he or she is a novice in the field. This scenario would be a violation of the redundancy principle (Kalyuga and colleagues 1999).

Common practice PowerPoint slides contain too much text

As mentioned, since 2001, harsh criticism of PowerPoint's presentation slide structure has surfaced in several popular publications (Keller 2003; Parker 2001; Patty 2007; Tufte 2003b). A common thread is that slides often overwhelm audiences with information—a situation that John Sweller states as arising from placing too many of the spoken words on the slide (Patty 2007).

How does PowerPoint lead users to overwhelm slides with too many words? As suggested earlier, the answer lies in the program's defaults. One problematic default is the bullet text default for the body of slides. Covering the middle and lower portions of the slide, as was shown in Figure 1, this text box default occupies 60% of the space on the slide master. By displaying such a large box, this default leads users, especially novices, to fill the slide with text. Doing so thus introduces extraneous cognitive load and increases the risk of violating the principle of redundancy.

As shown in Table 2, our analysis showed that the amount of text on common practice slides was high. For instance, the average number of words per slide at a U.S. technical conference was 33. In addition, because we knew how long the speakers at this conference presented, we could estimate the average amount of time spent on each slide. That amount of time was ~1 min. Simply put, 1 min is not enough time for an audience to read and comprehend 33 words on a slide and to listen to and comprehend the speaker, who is likely speaking at a rate of 120 words/min.

Common practice PowerPoint slides do not contain images that promote optimal comprehension and retention

Because text is the default for presenting information on a PowerPoint slide, the structure begins in violation of the multimedia principle. Granted, many presenters do make efforts to include graphics on slides. In our survey of common practice slides, we found graphics on 61% of the professional slides, 42% of the conference slides, and 61% of the graduate student slides.

At first glance, it may seem that the addition of photographs, drawings, diagrams, and graphs would allow the topic–subtopic slide to accommodate dual code theory and other research findings that favor the inclusion of images with text to bolster learning outcomes (Butcher 2006; Carney and Levin 2002; Hegarty and colleagues 1991; Mayer and Anderson 1992; Mayer and Gallini 1990; Paivio 1986). For instance, research has shown that the use of relevant, labeled images can support conceptual understanding of principle-driven information in novice learners (Mayer and Gallini 1990).

However, not all graphics are created equal, especially when they detract attention from important information.

TABLE 2. COMMON PRACTICE STATISTICS ON SLIDE TEXT

	Professionals: industry, laboratories		U.S. conference attendees		International PhD students	
Slide feature	Mean	SD	Mean	SD	Mean	SD
Number of lines of text per slide	8	3	8	2	8	2
Number of words per slide	43	18	33	12	39	13
Percent of slides per set with graphics	61	29	42	26	61	25
Number of slide sets considered	36		48		33	
Total number of slides considered	501		1,009		515	

We contend that the graphics typically selected for topic–subtopic slides do not contribute optimally to learning. The most helpful types of graphics, in terms of promoting comprehension and transfer of learning from text, either represent or explain concepts (Iding 2000; Ollerenshaw and colleagues 1997). However, because a phrase headline identifies the topic, rather than makes an assertion about the topic, presenters often do not select the graphic that explains the information on the slide. Rather, presenters tend to choose a graphic that, at best, replicates or depicts information already present on the slide.

To compound this problem, the large default text box in the body restricts the space available for graphics. Presenters therefore often compromise on the quality and size of the graphic and select graphics that represent only a portion of the content. However, graphics can give more valuable if they explain rather than just repeat content. Reiterating verbal information in graphic form may encourage understanding of a concept also presented in text, but unless the graphic signals the connection between concepts and explains the assertion that the presenter is making, the graphic reinforces only one part of the whole idea that is being conveyed. Although this reinforcement may aid in understanding part of the slide's information, it may inhibit the understanding of the overall slide.

To assess the types of graphics in our analysis of slides, we used a modified version of a classification system that was designed to catalog pictures that accompany expository text (Levin and Mayer 1993). Our system identified four levels of purpose that an image could fulfill: decorate, partially represent, represent, and explain. Decorative graphics were those deemed to be irrelevant to the text, such as entertaining clip art or decorative images on the slide background. Partially representative graphics identified portions of the slide's content, such as a photograph mirroring one out of three bullet points on a slide. Representational graphics represented or identified the main topic of the slide, such that the graphic pertained to the headline or to all of the text on the slide. Explanative graphics showed how the main principle, process, or system of the slide works. An example of an explanative graphic would be a flow diagram to show how energy moved through a system or a graph to show a key trend.

Only ~60% of the slides in our sample contain graphics—the remaining 40% of the slides contain just text. Also, as shown in Table 3, a significant number of graphics in these slides were partially representative, especially among the professionals and conference attendees. That is, these images mirrored only part of the text. These two findings run counter to the research on learning and multimedia presentation design, which emphasizes the importance of providing images that promote integration between concepts.

In summary, PowerPoint slides, as commonly designed, violate important learning principles including the multimedia, coherence, signaling, and redundancy principles. These slides often create extraneous cognitive load for audience members and therefore lead to poor comprehension and learning outcomes.

MULTIMEDIA PRINCIPLES APPLIED TO A–E SLIDES

Having its roots at Hughes Aircraft (Perry 1978) and Lawrence Livermore National Lab (Gottlieb 1984) and recently re-examined by independent researchers (Alley and Neeley 2005; Atkinson 2005; Doumont 2007; Markel 2009), the A–E slide structure addresses the mentioned failings of PowerPoint's default structure and in the process seeks to minimize the risk of introducing unnecessary cognitive load. In this

TABLE 3. COMMON PRACTICE STATISTICS ON IMAGE LEVEL

Classification	Definition	Professionals	Conference presenters	International PhD students
Decorates	Not relevant to text	5%	5%	0%
Partially represents	Represents only a portion of the slide's content	12%	15%	5%
Represents	Represents the main topic of the slide	53%	46%	57%
Explains	Explains the slide's main concept, process, or system	30%	35%	37%

section, we describe the A–E structure in relation to the previously discussed cognitive psychology principles, to make the argument that a reduction in cognitive load would occur if this structure is adopted. In addition, we assert that the structure is in agreement with cognitive load and dual code theories, the multimedia learning principles outlined by Mayer (2002, 2005b), and the research on learning from text that includes visual supplements (Hegarty and colleagues 1991). We then give recommendations for the design of slides that try to minimize cognitive load.

The A–E slide structure consists of a succinct sentence headline that states the main assertion, or the declaration, of the slide. That assertion is supported by visual evidence that serves to explain, organize, and interpret the content of the headline. Such visual evidence includes photographs, drawings, graphs, equations, and words arranged visually. The slides in Figures 6–9 depict how the A–E structure can be used to present different types of technical content. Figure 6 is our A–E version of the infamous Boeing slide that Tufte (2003a) excoriated in *The Cognitive Style of PowerPoint*. Figure 7 shows our A−E version of a research slide presented at a technical conference (Settles and colleagues 2002). This research studied the reasons that dogs are so effective at detecting scents, and this slide presents one of those reasons. Figure 8 is a slide from a research presentation created by an international PhD student (Marthinsen and colleagues 2004). Note that the presenter could remove the text block in the body of the slide and communicate that portion of the message in the speech. Figure 9 is an A–E slide used to help teach a technical subject (Schreiber 2005).

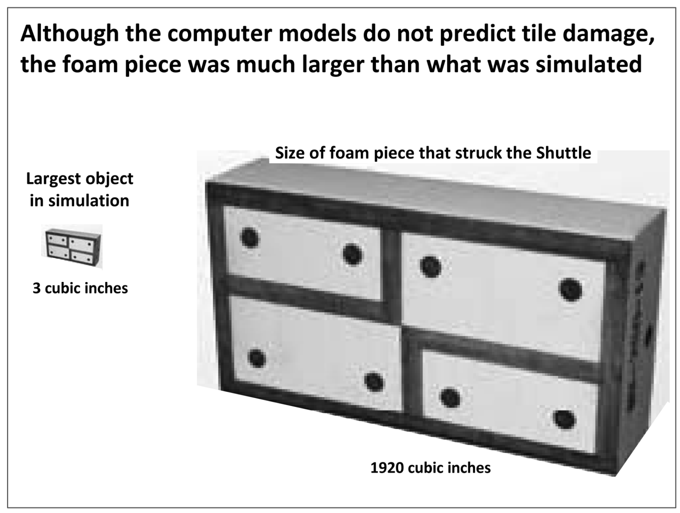

Figure 6. An A–E version of the infamous Boeing slide criticized by Tufte (2003).

A–E structure slides contain more images that promote optimal comprehension and retention

When used to convey technical information, the A–E structure theoretically should be much more effective than the traditional topic–subtopic structure at helping audience members learn. This increase in effectiveness occurs for several reasons. One is the requirement of visual evidence in the body of the slide. Perhaps the most striking difference between topic–subtopic and A–E structure slides is the replacement of the text in the slide body with a graphic that explains the assertion or main point of the slide. Therefore, not only does the A–E structure closely follow both the multimedia learning principle (Mayer 2005) and the principles of dual code theory (Paivio 1986) in that text and images are presented together, but an explicit emphasis is placed on the quality and purpose of the image(s) that are chosen.

The type of image included when using the structure is fundamentally different from the type of image en-

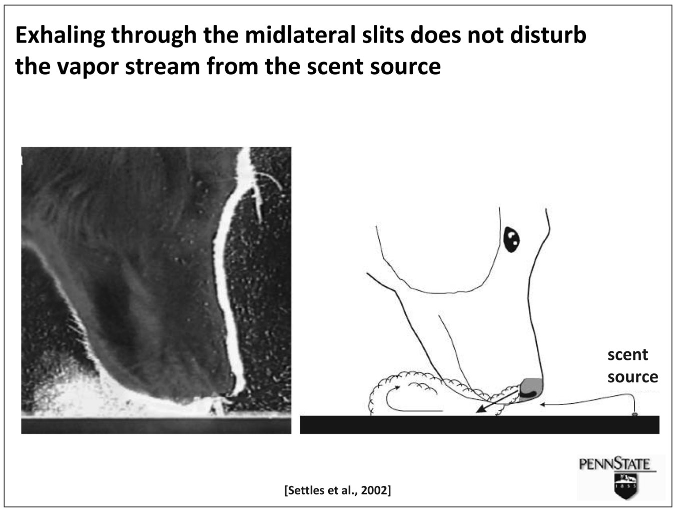

Figure 7. An A–E version of a research slide from a technical conference (Settles and colleagues 2002).

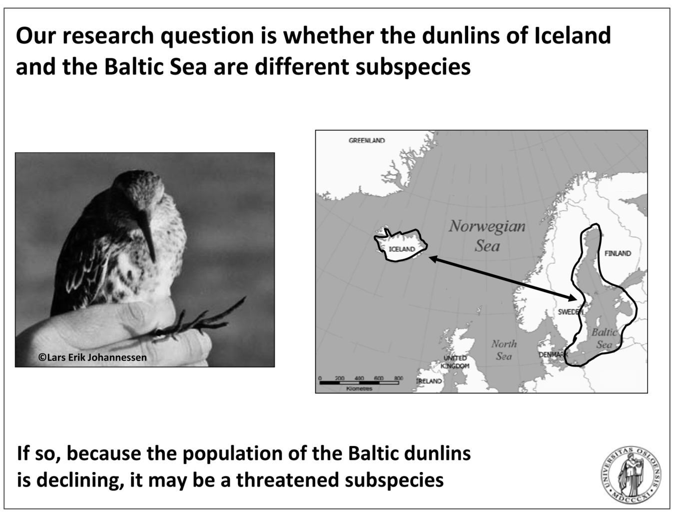

Figure 8. An A–E slide created by an international graduate student (Marthinsen and colleagues 2004).

couraged when using the topic–subtopic structure. In the A–E structure, because the required graphics are to serve as visual evidence to support the sentence headline, the presenter is discouraged from using decorative or partially representative images. Instead, this requirement promotes the thoughtful insertion of representative and explanative images into each and every slide used in a presentation. This requirement also contrasts with the lack of any graphic at all in ~40% of the common practice slides in our sample.

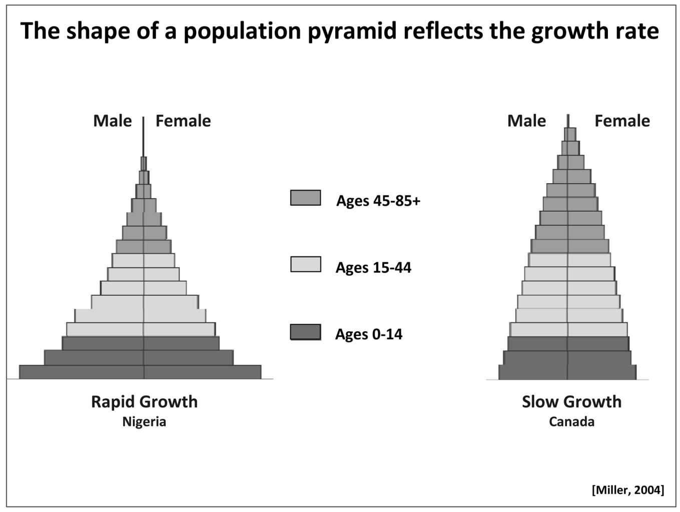

Figure 9. A classroom slide that follows the A–E structure (Schreiber 2005).

A–E structure slides follow more closely the multimedia principle of signaling

A frequent and significant criticism of the topic–subtopic slide structure is that it violates the principle of signaling by failing to adequately convey relationships between the phrase headline and the slide body and between the items listed within the slide body (Mayer 2005b; Patty 2007). The two hallmark features of the A–E slide structure—the sentence headline and the incorporation of supporting visual evidence—enhance signaling. Consider the difference in emphasis between the slide shown back in Figure 5 and the slide in Figure 9. Whereas the headline in the slide of Figure 5 identified only the topic (Synthesizing Diamonds), the headline in the A–E slide of Figure 9 used the sentence headline to establish both the topic and the perspective on the respective topic: "The shape of a population pyramid reflects the growth rate." Therefore, the audience received a cue to expect and attend to a specific perspective about the topic "population pyramids." In addition, the supporting visual evidence in this slide presents two example graphs that readily inform the audience of the relationship between shape of the pyramid and the growth of the country's population.

A–E structure slides follow more closely the multimedia principle of coherence

A frequent casualty of the topic–subtopic structure is succinctness, because presenters are often inclined—partly because of the generality of the phrase headline—to include more than the key information alone. The coherence principle requires that extraneous information be excluded from multimedia messages (Mayer 2005b). When applied to the A–E slide structure, the requirement of a sentence headline that states the slide's main assertion leads the slide creator to have more focus in designing the slide's body. In other words, the creator focuses on articulating and supporting an assertion rather than coming up with associated subtopics, which may very well be extraneous, and, if not extraneous, may not be clearly connected with one another.

Anecdotal evidence shows the importance of the sentence headline feature in teaching. In a personal communication, Professor Stacy Gleixner (2006), who heads a large NSF project (PRIME 2007) to teach principles of materials science at five different institutions and who has converted the slides in that project to the A–E structure, said: "When I create a sentence headline, I think about what main assertion I want the students to remember from that slide. Just that act makes my lectures more focused." This comment echoes the idea that the creation of the sentence headline forces the presenter to identify key concepts that relate to the topic and the presenter's own perspective on that topic and that such careful consideration of which concepts to present should reduce intrinsic cognitive load. The A–E slide back in Figure 9 captures the focus that slides following this structure have.

A–E structure slides follow more closely the multimedia principle of redundancy

The design principle of redundancy states that people learn more deeply from pictures and narration than from pictures, narration, and written words (Mayer 2005a). This principle acknowledges that simultaneous processing of narration and written text overwhelms the verbal portion of working memory (Baddeley 2003; Thompson and Paivio 1994). At first glance, the A–E design does not seem to follow this principle, because the headline containing the main assertion of the slide would also be stated in some form by the presenter. Moreover, the topic–subtopic structure's simplified heading would seem to reduce extraneous load that may occur when visual and auditory input is combined. However, we contend that the A–E headline does not violate the principle of redundancy because of the relative priority given to text elsewhere on the slide. The sentence assertion of the A–E headline is a brief summary of the speech that the presenter delivers for the slide, rather than a repetition of the entire text (Atkinson 2005, 208–216, 2006). Hearing and seeing a great deal of verbal information in a multimedia presentation can increase cognitive load (Kalyuga and colleagues 1999).

In an A–E presentation, the presenter should spend at least 1.5 min speaking about the typical slide (Alley 2003, 116). For a typical presenter, that would mean ~180 words of speech are to be summarized by a sentence headline that is to be no more than two lines (Alley 2003; Atkinson 2005; Doumont 2007). Clearly, when using the A–E structure, the presenter cannot resort to simply reading from the slide. The risk of violating the principle of redundancy is thus minimized, even for the novice presenter.

FUTURE DIRECTIONS, RECOMMENDATIONS, AND CHALLENGES

The advantages inherent within the A–E structure have led to a surge of interest in teaching and learning this structure—see Neeley and colleagues (2009) in this issue of *Technical communication*. In addition, research is underway to examine the specific effects of this structure on the comprehension and retention of information by audience members. Even though only a few formal experiments have been published on this structure (for example, Alley and colleagues 2006), confidence in the benefits of adopting the structure is already growing. As just one example, institutions in Norway invested $110,000 in 2009 for a presentations workshop for ~70 PhD students and postdocs in science and engineering. In this presentations workshop, the A–E slide structure was the cornerstone (Alley and colleagues 2009). For readers interested in more information about the design principles of the A–E structure, several publications exist (Alley 2004; Alley and Neeley 2005; Atkinson 2005; Doumont 2007; Jennings 2009; Markel 2009).

In this article, we drew attention to principles of multimedia learning and to the importance of considering cognitive load when designing presentation slides. Several recommendations follow from our discussion. Presenters can minimize intrinsic load if they articulate underlying assumptions and connections between concepts. It is easier for the presenter to do these things if the starting point for the slide is an assertion rather than a topic. Once the speaker has articulated his or her assertion, he or she is in a position to craft a single sentence headline (taking up no more than two lines when written in 28-point font) on the slide. The assertion quickly orients the audience to the most important information and sets up an expectation in audience members that the body of the slide will support the assertion. A byproduct of this approach is that the slide has a more targeted focus and specifies the nature of conceptual relationships, thus addressing the coherence and signaling principles, respectively.

Extraneous load will subsequently be minimized if the sentence headline is supported by visual evidence. Although visual evidence adheres to the multimedia principle, when choosing graphics, the rubric that we used may be usefully evoked to decide whether a choice truly explains the assertion or whether it merely represents one or more concepts. The rubric also serves as a reminder to exclude decorative images.

The principles also point to what not to do when designing slides. In particular, we cautioned against the use of phrase headlines, bullet lists, and the use of a large amount of text on slides because these violate the multimedia, coherence, and signaling principles. These PowerPoint defaults (or minor variations of the defaults) increase the risk of overwhelming attentional and memory-related cognitive resources and therefore increase the risk of reduced comprehension. We do acknowledge, however, that presenters can create topic–subtopic slides more rapidly than A–E slides and that it is easier from the presenter's perspective to create and give talks using a topic–subtopic structure that relies primarily on default settings for headlines, body text, and images. In addition, as Neeley and colleagues (2009) point out, using the A–E structure requires more preparation on the part of the presenter for what he or she is going to say. The reason for this additional preparation is that the topics are no longer written in note form on the slides, as they commonly are on topic–subtopic slides. However, embracing this A–E approach requires a shift away from what is easier for the presenter to generate and toward what is easier for the audience to consume. TC

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